6.5. Radiated Emissions in Restricted and non-Restricted bands

Limits & methods:

FCC requirements	15.247(d), 15.209, 15.205		
Test procedure	ANSI 63.10 section 11.12.1. Radiated measurement		
Operating Frequencies	2402MHz 2440MHz 2480MHz		
Ambient Temperature 22^{0}C	Relative Humidity 46%	Air Pressure 1006hPa	

Limit

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits.
Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see below)

FREQUENCIES (MHz)	FIELD STRENGTH (microvolts/meter)	MEASUREMENT DISTANCE (meters)
0.009 ~ 0.490	2400/F(kHz)	300
0.490 ~ 1.705	24000/F(kHz)	30
1.705 ~ 30.0	30	30
30 ~ 88	100	3
88 ~ 216	150	3
216 ~ 960	200	3
Above 960	500	3

Test procedure

The frequency spectrum was investigated from the lowest radio frequency signal generated in the equipment and up to ten harmonics. The measurements were performed in hopping transmission mode of operation for carrier (channel) frequency at bottom, middle and at the top of 2402MHz to 2480MHz frequency band and maximum transmitting data rate.

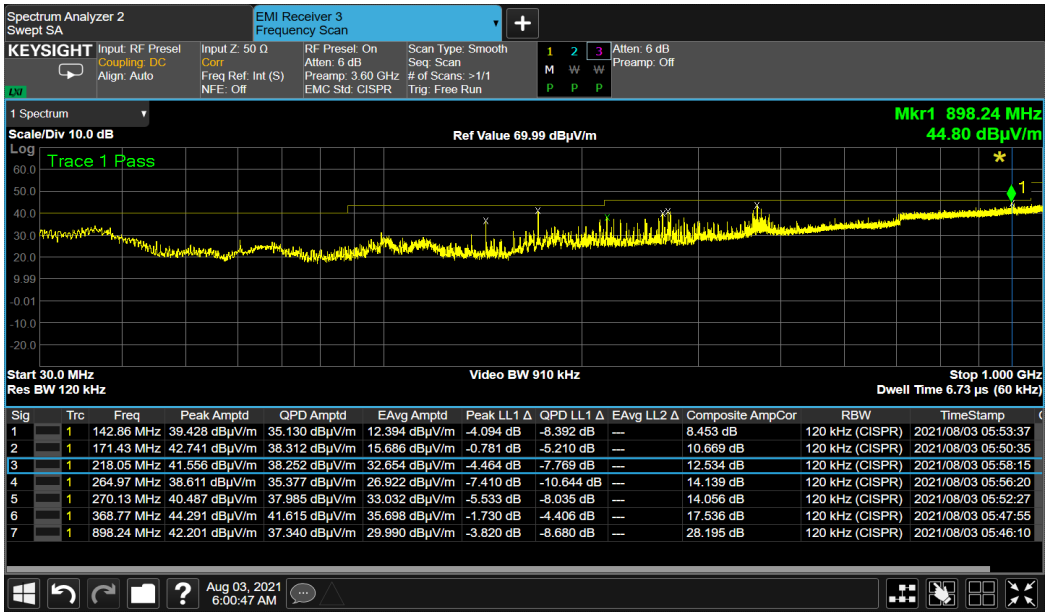
Results:

Range: 9kHz-30MHz
All detected emissions in this range meet the -20dBc requirement.

Frequency Carrier 2402 MHz

Range: below 1GHz

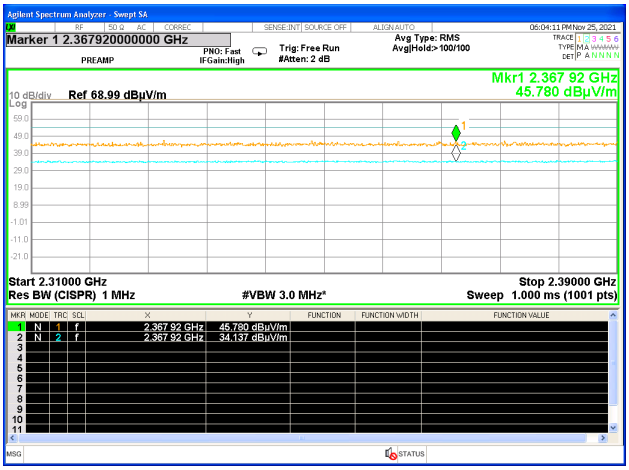
Frequency MHz	Peak, dBµV/m	QP, dBµV/m	QP Limit, dBµV/m	Delta QP dB	Verdict	Ref. Plot #
142.86	39.42	35.13	43.52	-8.39	Pass	14
171.43	42.74	38.31	43.52	-5.21	Pass	
218.05	41.55	38.25	46.02	-7.77	Pass	
264.97	38.61	35.37	46.02	-10.65	Pass	
270.13	40.48	37.98	46.02	-8.04	Pass	
368.77	44.29	41.61	46.02	-4.41	Pass	
898.24	42.201	37.34	46.02	-8.68	Pass	



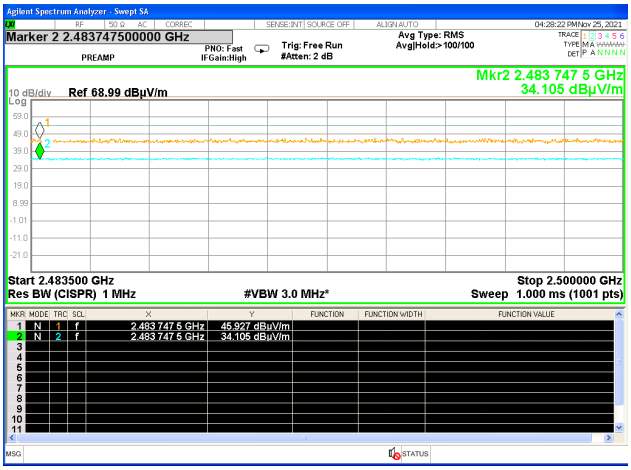
Plot 14

Range: 1GHz-25GHz

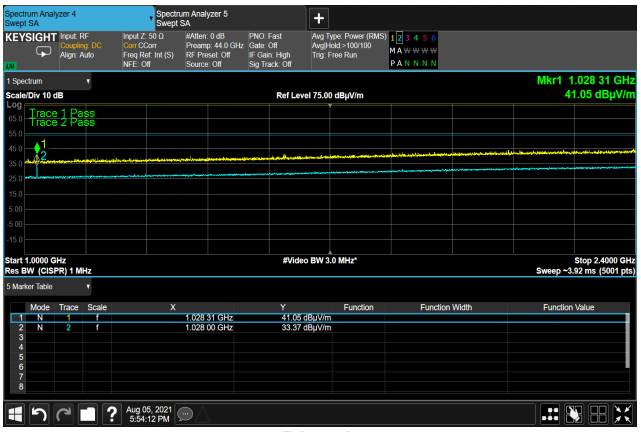
Frequency MHz	Radiated emission, dBµV/m	Peak Lim, dBµV/m	Avg Lim, dBµV/m	Margin dB	Note	Verdict	Ref. Plot #
1028	41.05	74	-	-32.95	Detector Pk	Pass	17
1028	33.37	-	54	-20.63	Detector Avg	Pass	17
2367.92	45.78	74	-	-28.22	Detector Pk	Pass	15
2367.92	34.13	-	54	-19.87	Detector Avg	Pass	15
2483.74	45.92	74		-28.08	Detector Pk	Pass	16
2483.74	34.10		54	-19.9	Detector Avg	Pass	16
5460	47.60	74	-	-26.4	Detector Pk	Pass	18
5460	39.16	-	54	-14.84	Detector Avg	Pass	18
11464	56.05	74	-	-17.95	Detector Pk	Pass	19
11464	43.45	-	54	-10.55	Detector Avg	Pass	19
14481	56.60	74	-	-17.4	Detector Pk	Pass	20
14481	45.56	-	54	-8.44	Detector Avg	Pass	20
23750	48.68	74	-	-25.32	Detector Pk	Pass	21
23750	36.87	-	54	-17.13	Detector Avg	Pass	21



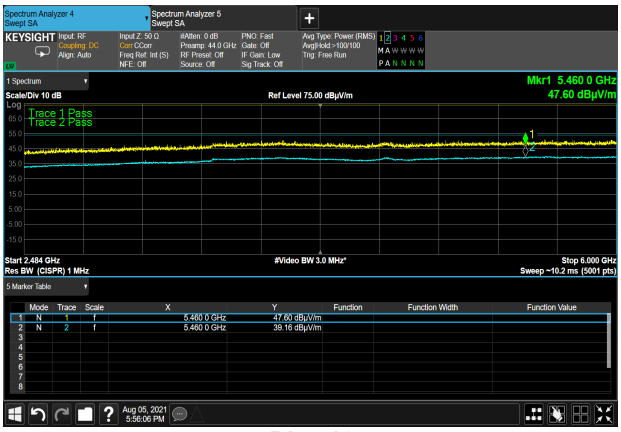
Plot 15



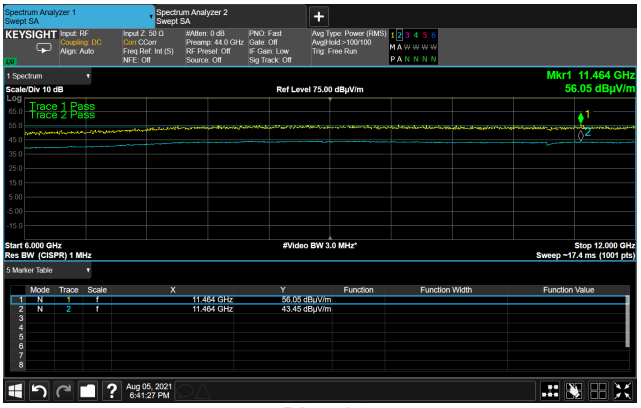
Plot 16



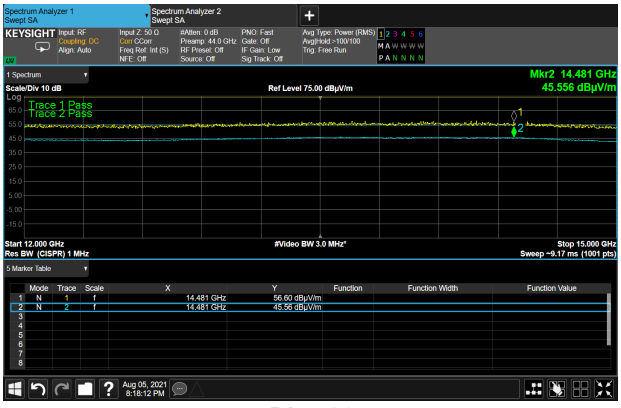
Plot 17



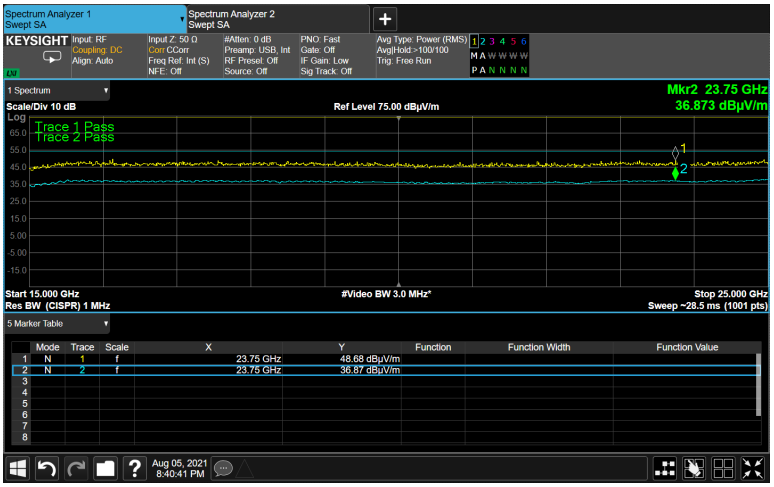
Plot 18



Plot 19



Plot 20

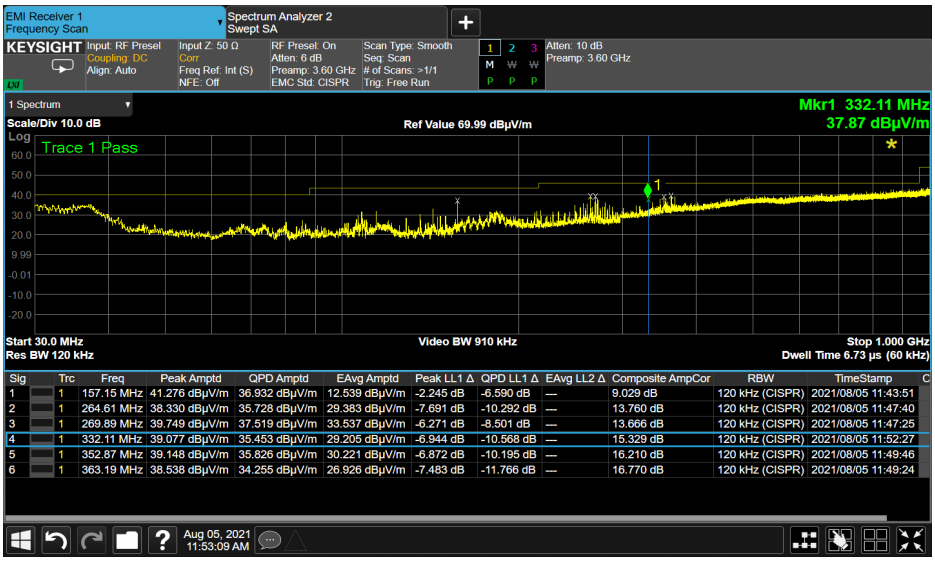


Plot 21

Frequency Carrier 2440 MHz

Range: below 1GHz

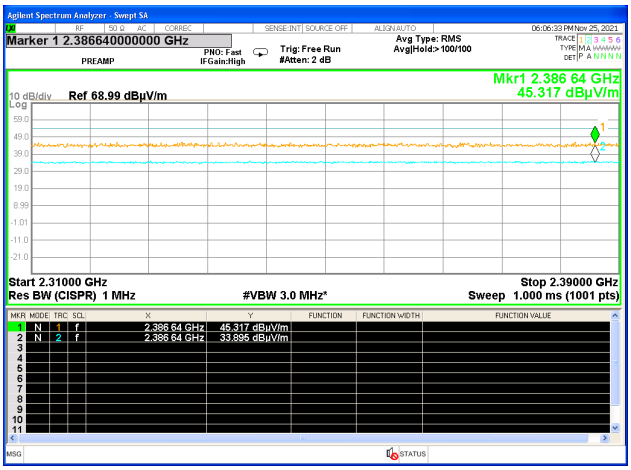
Frequency MHz	Peak, dBµV/m	QP, dBµV/m	QP Limit, dBµV/m	Delta QP dB	Verdict	Ref. Plot #
157.15	41.27	36.93	43.52	-6.59	Pass	22
264.61	38.33	35.72	43.52	-7.8	Pass	
269.89	39.74	37.51	46.02	-8.51	Pass	
332.11	39.07	35.45	46.02	-10.57	Pass	
352.87	39.14	35.82	46.02	-10.2	Pass	
363.19	38.53	34.25	46.02	-11.77	Pass	



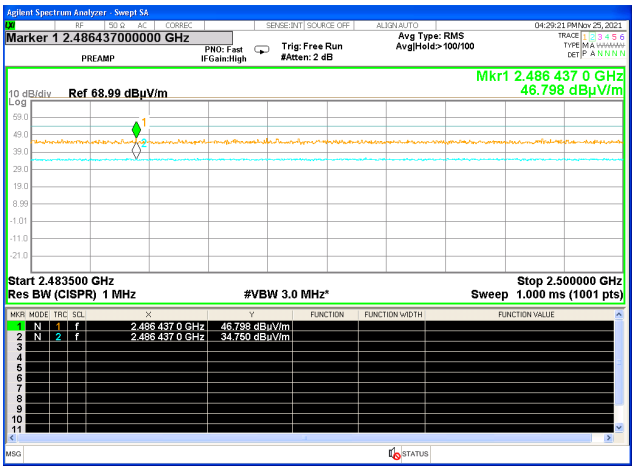
Plot 22

Range: 1GHz-25GHz

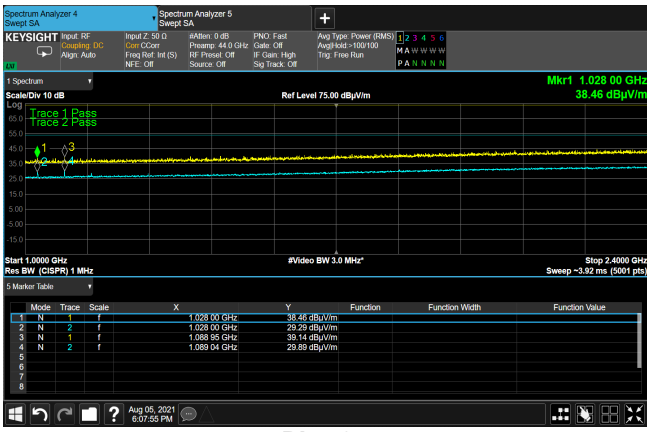
Frequency MHz	Radiated emission, dBµV/m	Peak Lim, dBµV/m	Avg Lim, dBµV/m	Margin dB	Note	Verdict	Ref. Plot #
1028	28.46	74	-	-45.54	Detector Pk	Pass	25
1028	29.29	-	54	-24.71	Detector Avg	Pass	25
1088	39.14	74	-	-34.86	Detector Pk	Pass	25
1089	29.89	-	54	-24.11	Detector Avg	Pass	25
2386.64	45.31	74	-	-28.69	Detector Pk	Pass	23
2386.64	33.89	-	54	-20.11	Detector Avg	Pass	23
2486.43	46.79	74	-	-27.21	Detector Pk	Pass	24
2486.43	34.75	-	54	-19.25	Detector Avg	Pass	24
3234	50.36	74	-	-23.64	Detector Pk	Pass	26
3234	43.68	-	54	-10.32	Detector Avg	Pass	26
11131	54.91	74	-	-19.09	Detector Pk	Pass	27
11131	43.31	-	54	-10.69	Detector Avg	Pass	27
14481	55.50	74	-	-18.5	Detector Pk	Pass	28
14481	45.66	-	54	-8.34	Detector Avg	Pass	28
23700	49.98	74	-	-24.02	Detector Pk	Pass	29
23700	37.56	-	54	-16.44	Detector Avg	Pass	29



Plot 23

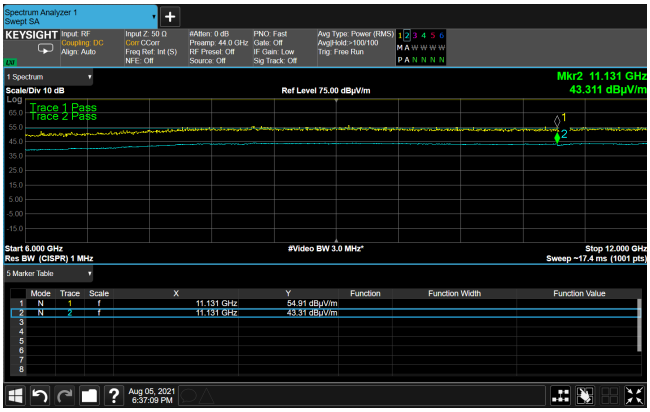


Plot 24

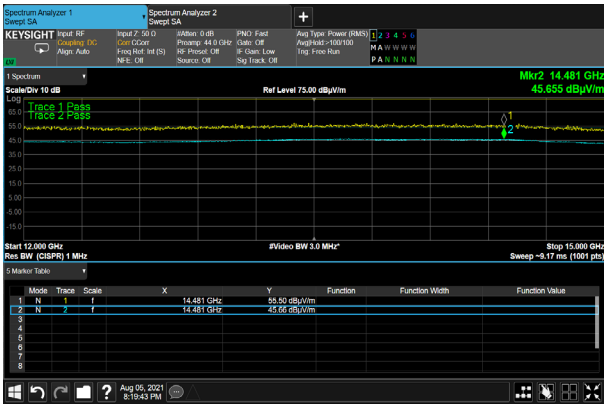


Plot 25

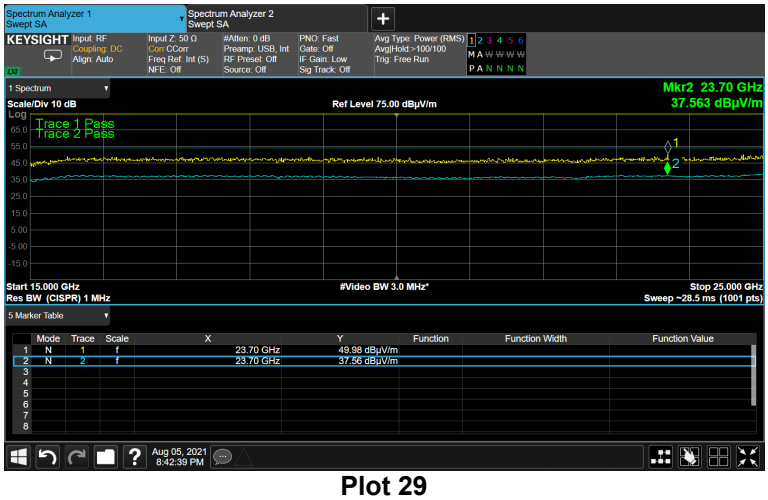
Plot 26



Plot 27



Plot 28

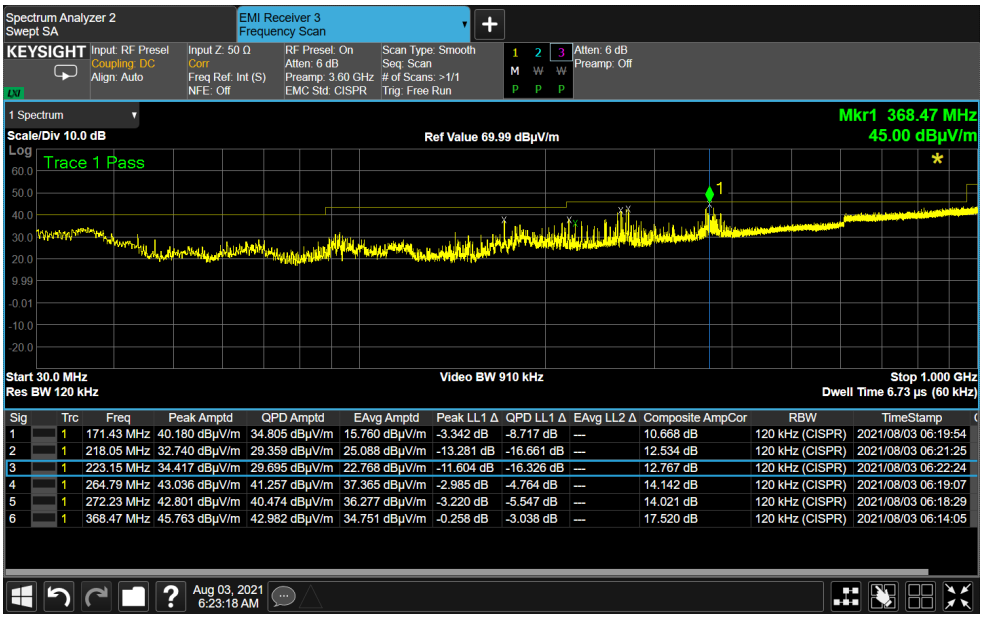


Plot 29

Frequency Carrier 2480 MHz

Range: below 1GHz

Frequency MHz	Peak, dBµV/m	QP, dBµV/m	QP Limit, dBµV/m	Delta QP dB	Verdict	Ref. Plot #
171.43	40.18	34.80	43.52	-8.72	Pass	30
218.05	32.74	29.35	46.02	-16.67	Pass	
223.15	34.41	29.69	46.02	-16.33	Pass	
264.79	43.03	41.25	46.02	-4.77	Pass	
272.23	4.80	40.47	46.02	-5.55	Pass	
368.47	45.75	42.98	46.02	-3.04	Pass	

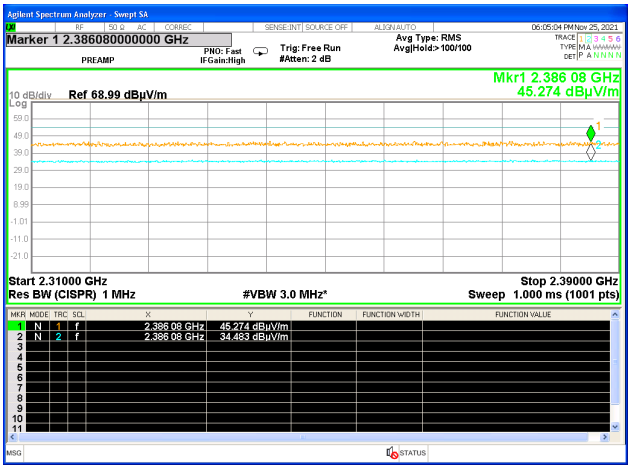


Sig	Trc	Freq	Peak Amptd	QPD Amptd	EAvg Amptd	Peak LL1 Δ	QPD LL1 Δ	EAvg LL2 Δ	Composite AmpCor	RBW	TimeStamp
1	1	171.43 MHz	40.180 dBµV/m	34.805 dBµV/m	15.760 dBµV/m	-3.342 dB	-8.717 dB	---	10.668 dB	120 kHz (CISPR)	2021/08/03 06:19:54
2	1	218.05 MHz	32.740 dBµV/m	29.359 dBµV/m	25.088 dBµV/m	-13.281 dB	-16.661 dB	---	12.534 dB	120 kHz (CISPR)	2021/08/03 06:21:25
3	1	223.15 MHz	34.417 dBµV/m	29.695 dBµV/m	22.768 dBµV/m	-11.604 dB	-16.326 dB	---	12.767 dB	120 kHz (CISPR)	2021/08/03 06:22:24
4	1	264.79 MHz	43.036 dBµV/m	41.257 dBµV/m	37.365 dBµV/m	-2.985 dB	-4.764 dB	---	14.142 dB	120 kHz (CISPR)	2021/08/03 06:19:07
5	1	272.23 MHz	42.801 dBµV/m	40.474 dBµV/m	36.277 dBµV/m	-3.220 dB	-5.547 dB	---	14.021 dB	120 kHz (CISPR)	2021/08/03 06:18:29
6	1	368.47 MHz	45.763 dBµV/m	42.982 dBµV/m	34.751 dBµV/m	-0.258 dB	-3.038 dB	---	17.520 dB	120 kHz (CISPR)	2021/08/03 06:14:05

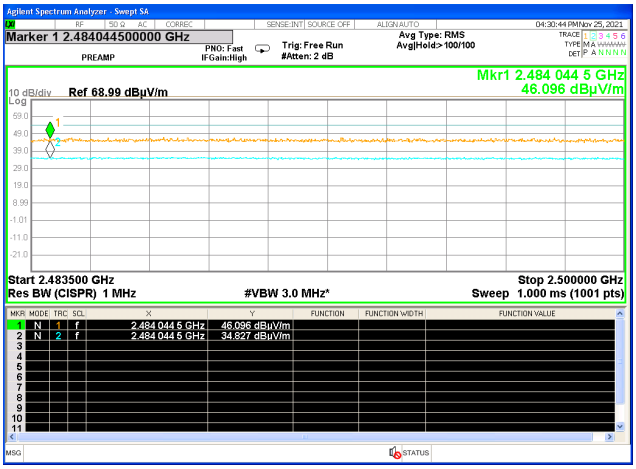
Plot 30

Range: 1GHz-25GHz

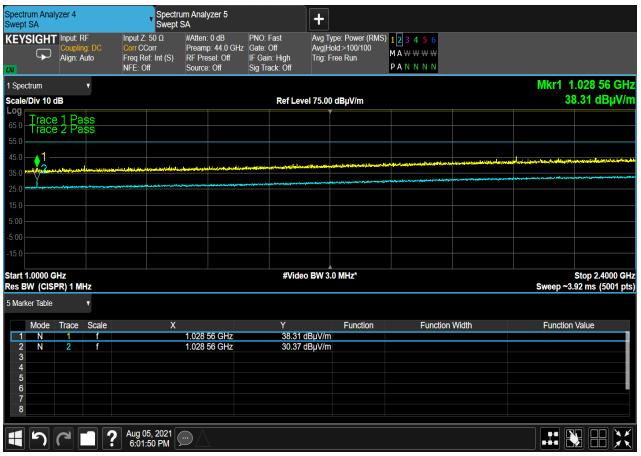
Frequency MHz	Radiated emission, dBµV/m	Peak Lim, dBµV/m	Avg Lim, dBµV/m	Margin dB	Note	Verdict	Ref. Plot #
1028	38.31	74	-	-35.69	Detector Pk	Pass	33
1028	30.37	-	54	-23.63	Detector Avg	Pass	33
2386.08	45.27	74		-28.73	Detector Pk	Pass	31
2386.08	34.48	-	54	-19.52	Detector Avg	Pass	31
2484.044	46.096	74		-27.904	Detector Pk	Pass	32
2484.44	34.827	-	54	-19.173	Detector Avg	Pass	32
5460	47.13	74	-	-26.87	Detector Pk	Pass	34
5460	39.33	-	54	-14.67	Detector Avg	Pass	34
8333	53.35	74	-	-20.65	Detector Pk	Pass	35
8333	43.83	-	54	-10.17	Detector Avg	Pass	35
12204	55.57	74	-	-18.43	Detector Pk	Pass	36
12204	44.04	-	54	-9.96	Detector Avg	Pass	36
15620	49.04	74	-	-24.96	Detector Pk	Pass	37
15620	37.74	-	54	-16.26	Detector Avg	Pass	37



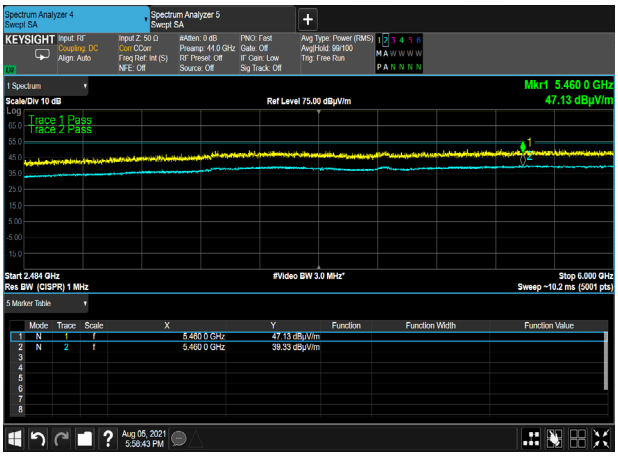
Plot 31



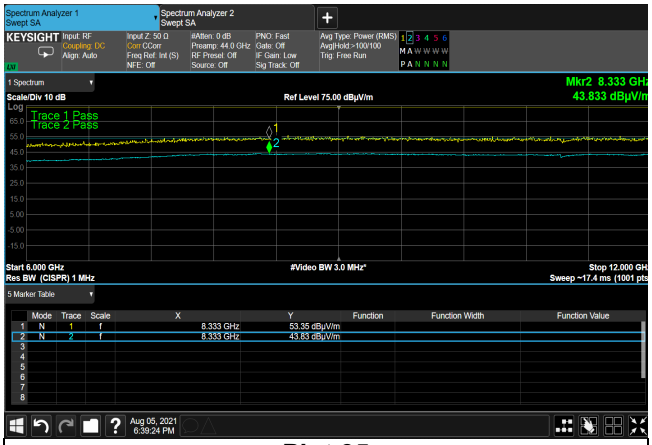
Plot 32



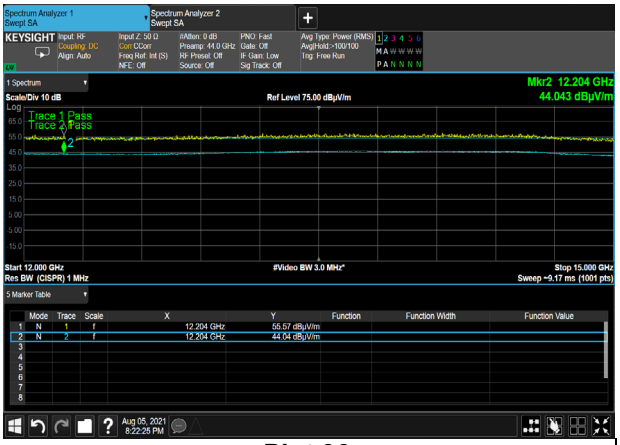
Plot 33



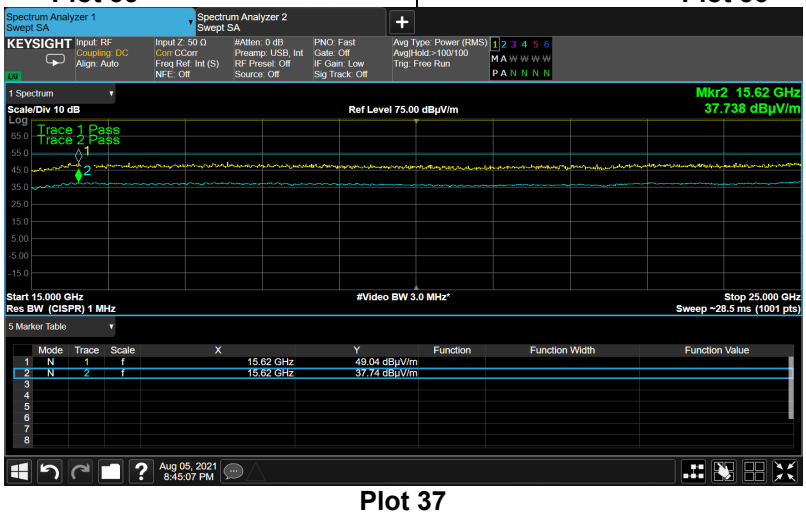
Plot 34



Plot 35



Plot 36



Plot 37

6.6. Band-edge compliance of RF conducted emissions

Limits & methods:

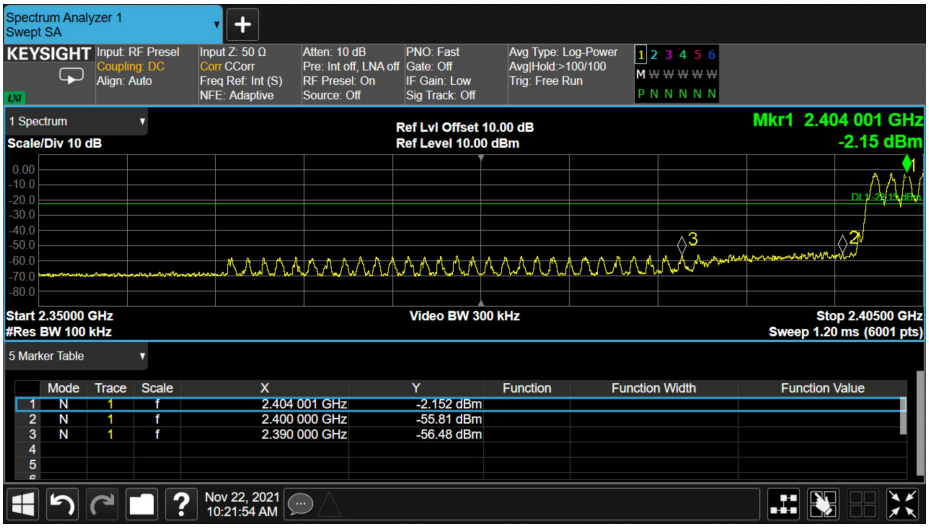
FCC requirements	15.247(d)		
Test procedure	ANSI 63.10 Section 7.8.6 Conducted measurement		
Operating Freq. Band/ Modulation	2402MHz 2440 MHz 2480MHz		
Ambient Temperature 22^{0}C	Relative Humidity 46%	Air Pressure 1006hPa	

Limit

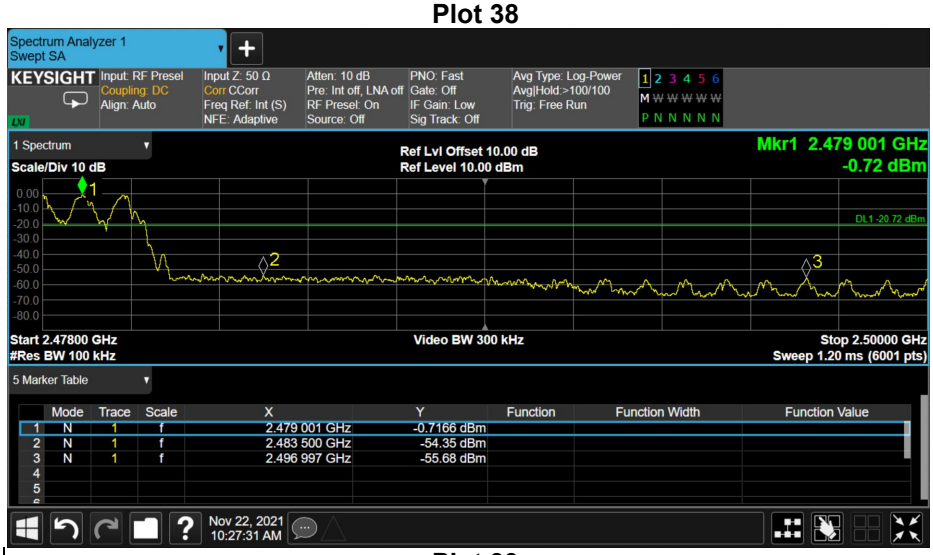
Operating frequency range, MHz	RF conducted emission limit
2400 – 2483.5	In any 100 kHz bandwidth outside the frequency band the radio frequency power shall be at least 20 dB below that in the 100 kHz bandwidth within the band

Results:

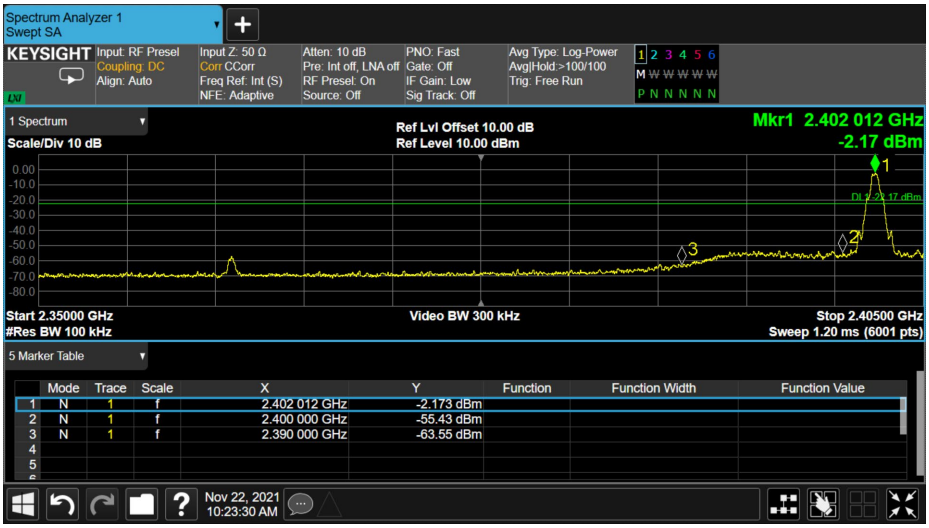
Channel #	Frequency, MHz	Measured result, dBm	Left border 2400 MHz, dbm	Right border 2483.5 MHz, dbm	Min. Limit in any 100kHz band, dBc	Verdict	Plot #
0	2402		-55.43	-	-20	Pass	40
Hopping	-		-55.81	-		Pass	38
78	2480		-	-54.09		Pass	41
Hopping	-		-	-54.35		Pass	39



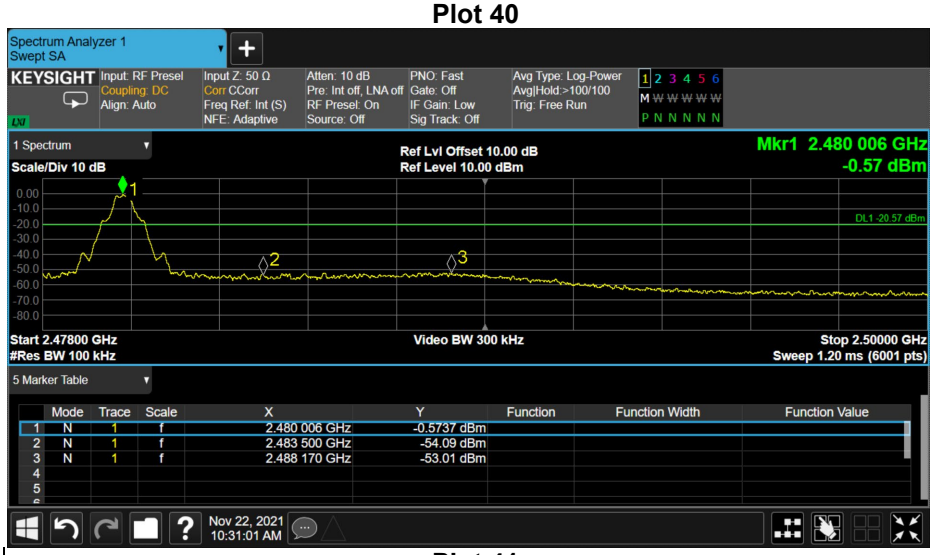
Plot 38



Plot 39



Plot 40



Plot 41

7. AC power line conducted emission measurement

Limits & methods:

FCC requirements	15.207		
Test procedure	ANSI 63.10 Section 6.2		
Ambient Temperature 22^{0}C	Relative Humidity 46%	Air Pressure	1006hPa

Limit:

Frequency, MHz	Class B equipment, dB (μV)	
	QP	AVRG
0.15 - 0.5	66 - 56*	56 - 46*
0.5 - 5	56	46
5 - 30	60	50

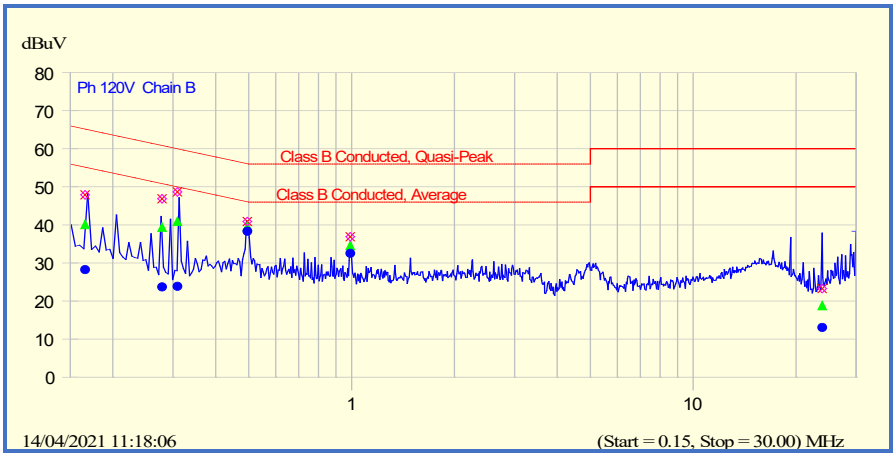
* Decreases linearly with the logarithm of the frequency.

Test Procedure:

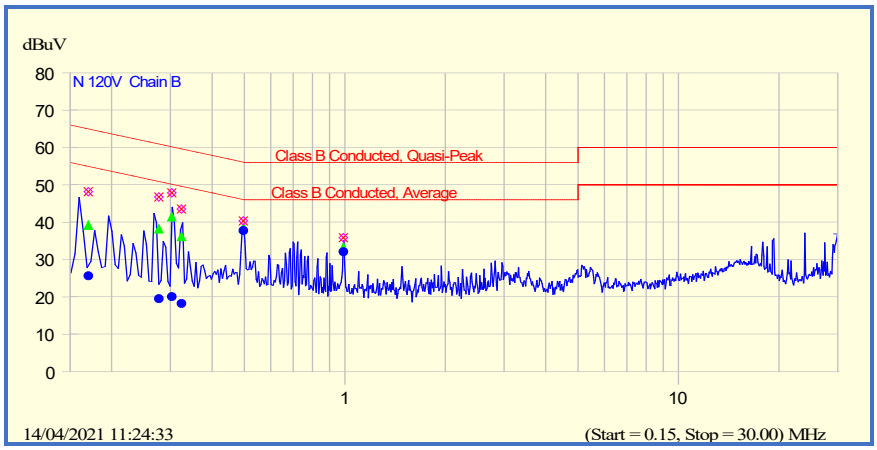
EUT was connected to 120VAC main via auxiliary PoE power supply.
The EUT was placed on a table in shielded room at a height 80 cm from floor and 40 cm from the vertical reference plane and at more than 80 cm from any other metal surfaces. The measurements were performed at mains terminals by means of LISN, connected to spectrum analyzer in the frequency range as referred to in the table above. The measurements were made with quasi-peak(CISPR) and average detectors. The position of the EUT cables was varied to determine maximum emission level.

Results:

The results are presented in Plots # 28-29.



Frequency MHz	Peak dBµV	QP dBµV	Lim QP dBµV	QP-QP Limit dB	Avg dBµV	Lim Avg dBµV	Avg - Avg Limit dB
0.17	47.9	40.1	65.2	-25.1	28.3	55.2	-26.9
0.28	46.9	39.4	60.9	-21.5	23.7	50.9	-27.1
0.31	48.7	40.9	60.0	-19.1	23.9	50.0	-26.1
0.50	40.9	39.6	56.1	-16.5	38.4	46.1	-7.7
0.99	36.9	34.6	56.0	-21.4	32.5	46.0	-13.5
23.87	23.3	18.8	60.0	-41.2	13.1	50.0	-36.9



Frequency MHz	Peak dBµV	QP dBµV	Lim QP dBµV	QP-QP Limit dB	Avg dBµV	Lim Avg dBµV	Avg - Avg Limit dB
0.17	48.2	39.2	64.9	-25.8	25.6	54.9	-29.3
0.28	46.8	38.2	60.9	-22.7	19.5	50.9	-31.4
0.30	47.9	41.4	60.2	-18.7	20.1	50.2	-30.1
0.32	43.5	36.1	59.6	-23.5	18.3	49.6	-31.3
0.50	40.4	38.5	56.1	-17.6	37.8	46.1	-8.3
0.99	35.9	33.3	56.0	-22.7	32.1	46.0	-13.9

Plot 42- Plot 43
Conducted emission on 120VAC mains. Phase & Neutral

8. Antenna requirements

Excerpt from §15.203 of the FCC Rules/Regulations:

"An intentional radiator antenna shall be designed to ensure that no antenna other than that furnished by the responsible party can be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section."

The antenna of the device is built-in non detachable antenna printed on the PCB (refer to Picture #1).
There are no provisions for connection to an external antenna.

Conclusion: The unit complies with the requirement of §15.203.

9. Appendix 1: Test equipment used

All measurements equipment is on SII calibration schedule with a recalibration interval not exceeding one year.

Instrument	Manufac-turer	Model	SII No.	Last calibration date	Next calibration date
EMI Analyzer 10 kHz - 26.5 GHz	HP	E7405A	4944	09/20	09/21
EMI RECEIVER-MXE 3Hz-44GHz	Agilent	N9038B	6505208	04/21	04/22
LISN 9 kHz – 30 MHz	FCC	LISN-50/250-32-4-16	5023	03/21	03/23
Active Receiving Loop Antenna	ETS-Lindgren	6507	00144641	11/20	04/22
Bigonilog Antenna 20 MHz - 6000 MHz	ETS-Lindgren	3142D	146490	08/19	08/21
Double Ridged Waveguide Antenna 1-18 GHz	EMCO	3115	0143138	07/21	07/23
Antenna Broad-Band Horn, 14 GHz - 40 GHz	SCHWARBECK MESS-ELEKTRONIK	BBHA 9170	5854	07/21	07/23
Data +Power splitter	-	-	-	N/A	N/A
Semi Anechoic Chamber	ETS-Lindgren	RFSD-F/A-100	5002	N/A	N/A
Multi-Device Positioning Controller	ETS-Lindgren	2090	5002	N/A	N/A
Antenna Tower	ETS-Lindgren	2175	5002	N/A	N/A
Boresight Antenna Tower	ETS-Lindgren	2171B	5002	N/A	N/A
Turntable	ETS-Lindgren	2188	5002	N/A	N/A
Cable RF 1 m	SUCOFLEX	104PE	21325	04/21	04/22
Cable RF 3 m	VPO 2930	K30K30-5003-300cm5VI	005	04/21	04/22
Cable RF 3 m	VPO 2930	K30K30-5003-300cm6VI	006	04/21	04/22
Cable RF 3 m	VPO 2930	K30K30-5003-300cm7VI	007	04/21	04/22
Cable RF 3 m	VPO 2930	K30K30-5003-300cm8VI	008	04/21	04/22
Attenuator 10dB 5W	-	5W	6502987	04/20	04/22
Attenuator 20dB 5W	-	5W	6502992	04/20	04/22
USB preamplifier 2 GHz – 50 GHz	Keysight	U7227F	MY 55380004	04/21	04/22
Transient limiter 0.009-200 MHz	HP	11947A	3107105	10/20	10/21
Cable	EIM	RG 214/U	8 & 10	01/21	01/22

10. Appendix 2: Antenna Factor and Cable Loss

Cable Loss (RG214 (6 m) + 5005 (3.8 m) + 5005 (3 m))

No.	Frequency (MHz)	Attenuation (dB)	Frequency (MHz)	Attenuation (dB)	Frequency (MHz)	Attenuation (dB)	Frequency (MHz)	Attenuation (dB)
1	0.00	0.0	2.16	0.1	46.76	0.6	1011.06	3.0
2	0.11	0.0	2.27	0.1	49.10	0.7	1061.61	3.1
3	0.11	0.0	2.38	0.1	51.55	0.7	1114.70	3.1
4	0.12	0.0	2.50	0.1	54.13	0.7	1170.43	3.2
5	0.12	0.0	2.63	0.1	56.83	0.7	1228.95	3.3
6	0.13	0.0	2.76	0.1	59.68	0.8	1290.40	3.3
7	0.13	0.0	2.90	0.1	62.66	0.8	1354.92	3.4
8	0.14	0.0	3.04	0.1	65.79	0.8	1422.66	3.5
9	0.15	0.0	3.19	0.2	69.08	0.8	1493.80	3.6
10	0.16	0.0	3.35	0.2	72.54	0.9	1568.49	3.6
11	0.16	0.0	3.52	0.2	76.16	0.9	1646.91	3.7
12	0.17	0.0	3.70	0.2	79.97	0.9	1729.26	3.7
13	0.18	0.0	3.88	0.2	83.97	1.0	1815.72	3.8
14	0.19	0.0	4.08	0.2	88.17	1.0	1906.51	3.9
15	0.20	0.0	4.28	0.2	92.58	1.0	2001.83	3.9
16	0.21	0.0	4.50	0.2	97.21	1.0	2101.92	4.0
17	0.22	0.1	4.72	0.2	102.07	1.0	2207.02	4.0
18	0.23	0.1	4.96	0.2	107.17	1.1	2317.37	4.1
19	0.24	0.1	5.20	0.2	112.53	1.1	2433.24	4.1
20	0.25	0.1	5.46	0.2	118.15	1.1	2554.90	4.2
21	0.27	0.1	5.74	0.2	124.06	1.2	2682.65	4.2
22	0.28	0.1	6.02	0.2	130.26	1.2	2816.78	4.3
23	0.29	0.1	6.33	0.2	136.78	1.2	2957.62	4.3
24	0.31	0.1	6.64	0.2	143.62	1.3	3105.50	4.4
25	0.32	0.1	6.97	0.2	150.80	1.3	3260.77	4.4
26	0.34	0.1	7.32	0.2	158.34	1.3	3423.81	4.5
27	0.36	0.1	7.69	0.3	166.25	1.3	3595.00	4.5
28	0.37	0.1	8.07	0.2	174.57	1.4	3774.75	4.6
29	0.39	0.1	8.48	0.2	183.30	1.4	3963.49	4.6
30	0.41	0.1	8.90	0.2	192.46	1.5	4161.67	4.6
31	0.43	0.1	9.35	0.3	202.08	1.5	4369.75	4.6
32	0.45	0.1	9.81	0.3	212.18	1.6	4588.24	4.5
33	0.48	0.1	10.30	0.3	222.80	1.6	4817.65	7.0
34	0.50	0.1	10.82	0.3	233.94	1.6	5058.53	6.8
35	0.53	0.1	11.36	0.3	245.63	1.7	5311.46	7.2
36	0.55	0.1	11.93	0.3	257.92	1.7	5577.03	7.0
37	0.58	0.1	12.52	0.4	270.81	1.8	5855.88	8.1
38	0.61	0.1	13.15	0.3	284.35	1.8	6148.68	7.9
39	0.64	0.1	13.81	0.4	298.57	1.9	6456.11	8.3
40	0.67	0.1	14.50	0.4	313.50	1.9	6778.91	8.1
41	0.70	0.1	15.22	0.4	329.17	1.9	7117.86	8.4
42	0.74	0.1	15.98	0.4	345.63	2.0	7473.75	8.6
43	0.78	0.1	16.78	0.4	362.91	2.0	7847.44	8.7
44	0.81	0.1	17.62	0.4	381.06	2.0	8239.81	9.0
45	0.86	0.1	18.50	0.4	400.11	1.9	8651.80	9.7
46	0.90	0.1	19.43	0.4	420.12	1.9	9084.39	10.4
47	0.94	0.1	20.40	0.4	441.12	1.9	9538.61	11.0
48	0.99	0.1	21.42	0.4	463.18	1.9	10015.54	11.6
49	1.04	0.1	22.49	0.5	486.34	1.9	10516.32	11.9
50	1.09	0.1	23.62	0.4	510.65	2.2	11042.14	13.4
51	1.15	0.1	24.80	0.5	536.19	2.1	11594.25	13.9
52	1.20	0.1	26.04	0.5	563.00	2.3	12173.96	13.5
53	1.26	0.1	27.34	0.5	591.15	2.5	12782.66	14.0
54	1.33	0.1	28.71	0.4	620.70	2.4	13421.79	13.9
55	1.39	0.1	30.14	0.5	651.74	2.4	14092.88	15.7
56	1.46	0.1	31.65	0.5	684.33	2.7	14797.52	15.7
57	1.54	0.1	33.23	0.5	718.54	2.7	15537.40	16.6
58	1.61	0.1	34.89	0.5	754.47	2.6	16314.27	17.5
59	1.69	0.1	36.64	0.5	792.19	2.7	17129.98	17.7
60	1.78	0.1	38.47	0.6	831.80	2.7	17986.48	18.7
61	1.87	0.1	40.39	0.6	873.39	2.9	18000.00	18.3
62	1.96	0.1	42.41	0.6	917.06	2.8		
63	2.06	0.1	44.53	0.6	962.92	2.9		

Antenna Factor
Biconilog Antenna Model No: 3142D Ser.No: 146490. 3 m distance

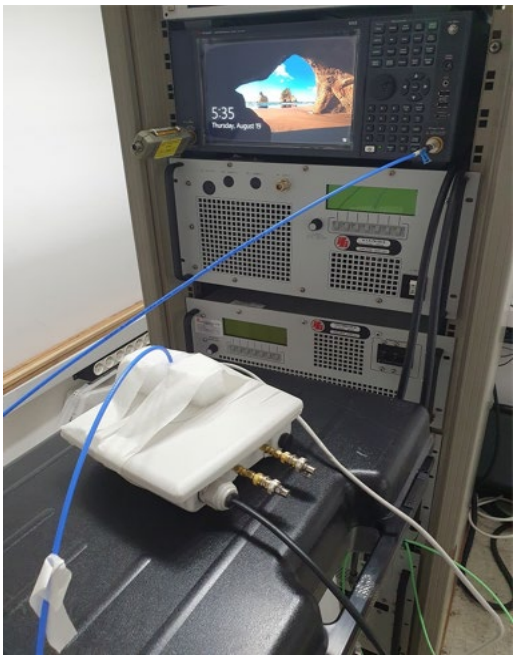
No.	f / MHz	ACF / dB/m	f / MHz	AF / dB/m
1	30	24.163	200	16.944
2	35	21.253	250	19.108
3	40	18.627	300	20.008
4	45	16.523	400	22.244
5	50	15.030	500	24.997
6	60	13.445	600	26.581
7	70	13.336	700	27.633
8	80	12.720	800	28.829
9	90	13.742	900	30.078
10	100	14.609	1000	30.820
11	120	13.716	1250	33.670
12	140	14.187	1500	36.896
13	160	14.964	1750	34.459
14	180	16.537	2000	35.148

Antenna Factor
Double Ridged Waveguide Horn Antenna manufacturer EMCO Type 3115
1 GHz to 18 GHz. 3 m distance

No.	f / MHz	AF / dB/m	f / MHz	AF / dB/m	f / MHz	AF / dB/m
1	1000	23.6	7000	36.6	13000	39.7
2	1500	25.5	7500	37.3	13500	40.3
3	2000	28.2	8000	37.0	14000	41.0
4	2500	27.6	8500	37.4	14500	40.8
5	3000	29.2	9000	37.7	15000	39.4
6	3500	30.5	9500	38.0	15500	38.8
7	4000	31.7	10000	38.2	16000	39.0
8	4500	31.9	10500	38.5	16500	40.1
9	5000	32.7	11000	38.6	17000	40.8
10	5500	33.8	11500	38.9	17500	42.2
11	6000	35.2	12000	38.8	18000	42.3
12	6500	35.7	12500	39.0		

11. Appendix 3: Test illustrations

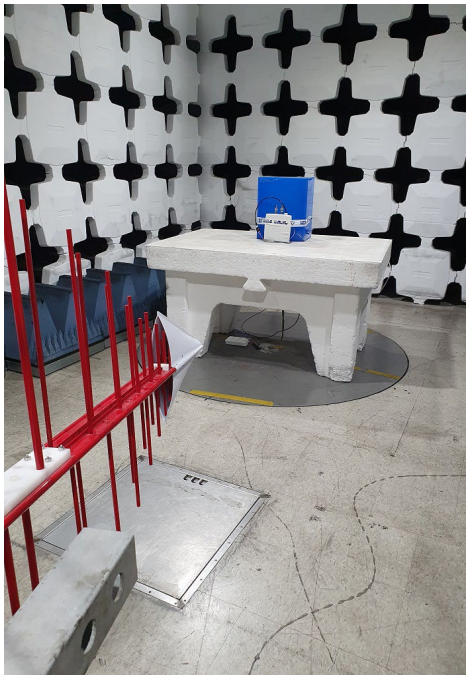
Picture 1
Connection to internal BT antenna.

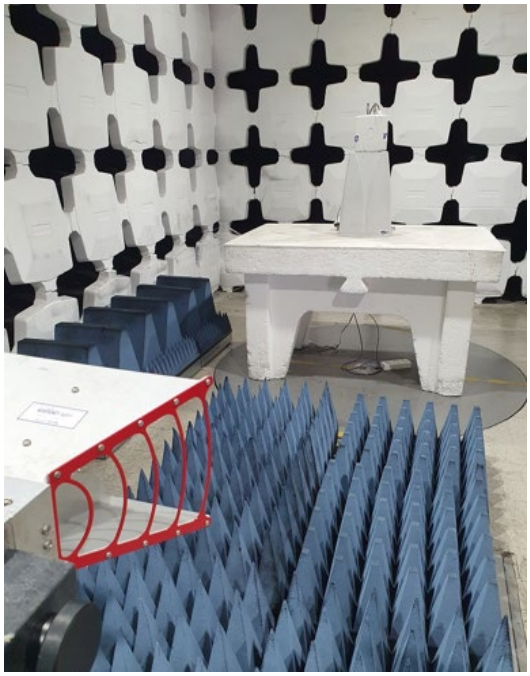


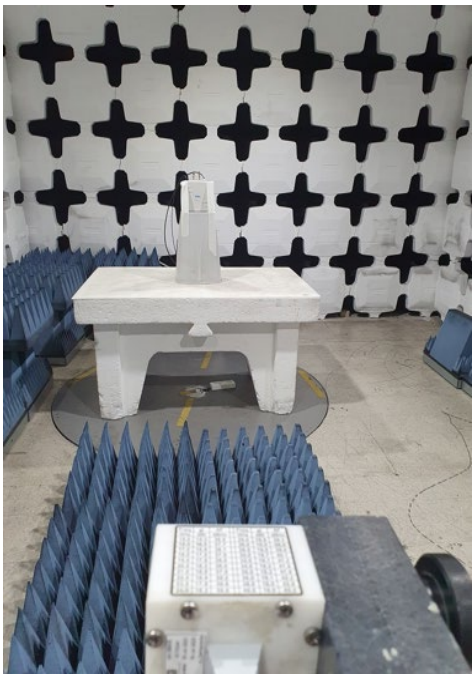
Picture 2
RF Conducted measurement test setup

Picture 3.
LAN-Power Splitter to use PoE technology

Picture 4.
AC power Adapter







Picture 5
Radiated spurious emission test setup.

END OF THE DOCUMENT